

Vivid Motor Imagery as an Adaptation Method for Head Turns on a Short-Arm Centrifuge

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Background: Artificial gravity (AG) has been proposed as a potential countermeasure to the debilitating physiological effects of long-duration space flight. The most economical means of implementing AG may be through the use of a short-radius (2m or less) centrifuge. For such a device to produce gravitational forces comparable to those on earth requires rotation rates in excess of 20 revolutions per minute (rpm). Head turns made out of the plane of rotation at these rates, as may be necessary if exercise is combined with AG, result in cross-coupled stimuli (CCS) that cause adverse side-effects including motion sickness, illusory sensations of motion, and inappropriate eye movements. Recent studies indicate that people can adapt to CCS and reduce these side-effects by making multiple head turns during centrifuge sessions conducted over consecutive days. However, about 25% of the volunteers for these studies have difficulty tolerating the CCS adaptation paradigm and often drop out due to motion sickness symptoms. The goal of this investigation was to determine whether vivid motor imagery could be used as a pseudo-stimulus for adapting subjects to this unique environment. **Methods:** Twenty-four healthy human subjects (14 males, 10 females), ranging in age from 21 to 48 years (mean 33, sd 7 years) took part in this study. The experimental stimuli were produced using the NASA JSC short-arm centrifuge (SAC). Subjects were oriented supinely on this device with the nose pointed toward the ceiling and head centered on the axis of rotation. Thus, centrifuge rotation was in the body roll plane. After ramp-up the SAC rotated clockwise at a constant rate of 23 rpm, producing a centrifugal force of approximately 1 g at the feet. Semicircular canal CCS were produced by having subjects make yaw head turns from the nose up (NU) position to the right ear down (RED) position and from RED to NU. Each head turn was completed in about one second, and a 30 second recovery period separated consecutive head movements. Participants were randomly assigned to one of three groups (n=8 per group): physical adapters (PA), mental adapters (MA), or a control group (CG). Each subject participated in a one hour test session on each of three consecutive days. Each test session consisted of an initial (pre-adaptation) period during which the subject performed six CCS maneuvers in the dark, followed by an adaptation period with internal lighting on the centrifuge (see below), and a final (post-adaptation) period during which six more CCS maneuvers were performed in the dark. For the PA group, the adaptation period consisted of performing 30 additional CCS maneuvers in the light. For the MA and CG group the centrifuge was ramped-down to 0 rpm after the pre-adaptation period and ramped back up to 23 rpm before the post-adaptation period. For the both of these groups, the adaptation period consisted of making 30 CCS maneuvers in the light with the centrifuge stationary (so no cross-coupling occurred). MA group subjects were instructed to vividly imagine the provocative sensations produced by the pre-adaptation CCS maneuvers in terms of

magnitude, duration, and direction of illusory body tilt, as well as any accompanying levels of motion sickness. CG group subjects were asked to answer low imagery-content questions (trivial pursuit) during each adaptation period head turn. During the 30 second recovery following each head turn, psychophysical data were collected including self-reports of motion sickness, magnitude and direction estimates of illusory body tilt, and the overall duration of these sensations. **Results:** A multilevel mixed-effects linear regression analysis performed on all response variables indicated that all three groups experienced some psychophysical adaptation across the three test sessions. For illusory tilt magnitude, the PA group exhibited the most overall adaptation, followed by the MA group, and the CG group. The slopes of these adaptation trajectories by group over day were significantly different from one another. For the perceived duration of sensations, the CG group again exhibited the least amount of adaptation. However, the rates of adaptation of the PA and the MA groups were indistinguishable, suggesting that the imagined pseudo-stimulus appeared to be just as effective a means of adaptation as the actual stimulus. The MA group's rate of adaptation to motion sickness symptoms was also comparable to the PA group. **Conclusions:** The use of vivid motor imagery may be an effective method for adapting to the illusory sensations and motion sickness symptoms produced by cross-coupled stimuli. For space-based AG applications, this technique may prove quite useful in retaining astronauts considered highly susceptible to motion sickness as it reduces the number of actual CCS required to attain adaptation.